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TECHNICAL COMMITTEE MEMORANDUM TCM 14/02

Wild Country Nitro Snap Gate Failure

Incident Ref. 05/14/C.SCH

SUMMARY

A climber experienced a snap gate karabiner failure during a sport climb in El Chorro, Spain. The climber took an approximately 3 metre fall that resulted in injury requiring stitches but has recovered fully. The received karabiner, a Wild Country Nitro is a relatively new model, and appeared to be in good condition generally. It is apparent that there is quite some (pre-incident) damage, probably from contact loading with various bolts during use. These abrasions have resulted in many "starter cracks" in the aluminium alloy karabiner.

Analysis shows that stresses may be sufficiently large, for failure to occur by an excessive bending moment that resulted fracture initiation from the abraded region in the karabiner, where the bending stress would have been of largest magnitude. Therefore, it is concluded that the karabiner probably failed due to wear and tear, followed by an unfortunate loading situation, rather than via a manufacturing or design fault. This case re-iterates the need for careful examination (and retirement when necessary) by the user, when using lightweight equipment.

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Date:	**29/01/2018**
Approved by the Technical Committee:	Phillip Tootell

1. INTRODUCTION

This snap gate was received from the climber after a fall of approximately 3 metres. The WC Nitro* is a fully sized, 35 g karabiner that is identical to the Helium karabiner with a modified nose on the wire gate to reduce manufacturing costs. The snap gate has an I-beam construction that is produced by hot forging. Each product is 3 Sigma Rated, UIAA, CE EN 12275, 7075 Alloy. All Wild Country karabiners are proof loaded to 10 kN and inspected by hand: www.wildcountry.com/products/karabiners/nitro-tech-wire/
*now discontinued

2. EXAMINATION

By comparing the rope side (1 Left) and gear side (1 Right) of the quickdraw, one may note plastic deformation and crack failure in the shoulder of the karabiner. The component otherwise appears as new, with no evidence of environmental degradation.

Figure 1. Shows (Left) rope side of the quick draw and (Right) the gear side that has failed at the radius where the rope runs.

Plastic deformation was found to be present, by the observation that the karabiner fits together either on the front side (2 Left) or the back side (2 Right), but not both. The nature of plastic deformation also indicates that failure has occurred via bending failure and crack propagation from the inside of the karabiner, outwards.

Figure 2. Closer examination of the karabiner shows that plastic deformation is apparent.

Several regions of the karabiner were noted to display scratches and abrasive pitting, likely due to movement of the karabiner under load whilst attached to a sharp metallic edge, such as a bolt hanger. This hypothesis follows logic because a typical bolt hanger is made of steel, which is much harder than the Aluminium karabiner. Shown in 3, these regions were identified by eye, and are indicated in the image. These were characterised in two magnitudes of severity; i) surface damage shown in squares and ii) up to deep groves in the order of a millimetre depth, likely effecting strength (circled).

Figure 3. Optical images of the whole karabiner with some locations of damage indicated (squared as minor/surface damage and circled as severe).

3. ANALYSIS

Aluminium 7000 series alloys such as the 7075 are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. Their strength and light weight is also desirable in other fields. Rock climbing equipment, bicycle components, in-line skating frames and hang glider airframes are commonly made from 7075 aluminium alloy.

The broken fracture surface was examined to determine the initial crack length (presumably from bolt damage on the karabiner) and a value of approximately 0.53-0.56 mm was obtained for the centre of the damaged region, see Figure 4. Due to the rough nature of the surface, it was difficult to be sure of the exact initial crack length.

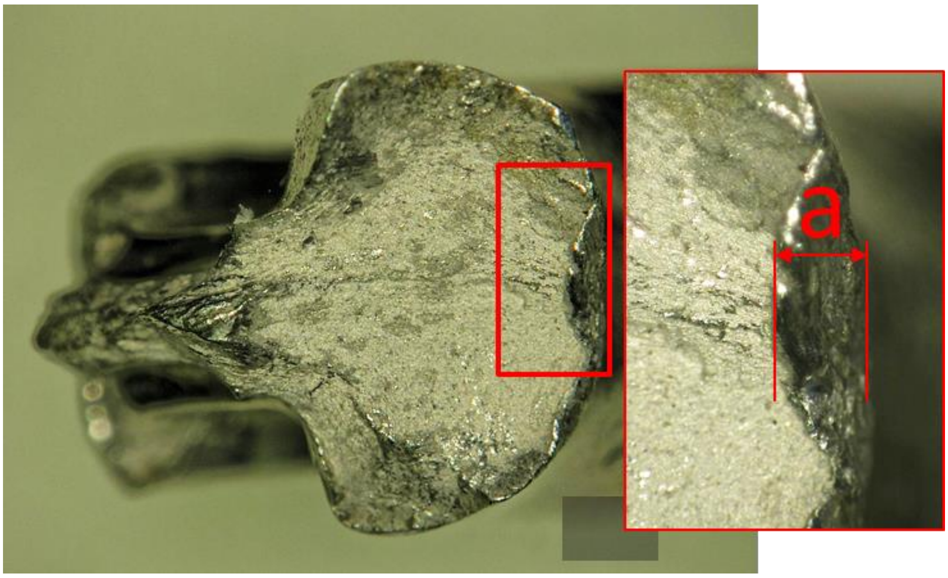


Figure 4. Optical image of the fracture surface.

The following calculations attempt to calculate the stress generated by a fall on the karabiner and compare these to the fracture toughness of the karabiner to estimate if such a fall could indeed result in fracture. It is postulated that as a worst case scenario, a maximum bending moment would be generated with the longest lever arm (i.e. if the nose of the karabiner had hooked a bolt ring and was subsequently loaded).

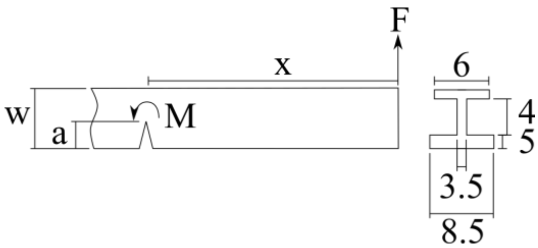


Figure 5. Part geometry of the WC Nitro karabiner that was studied.

The fall of a 75 kg mass from with 1.5 m rope paid out (for an app. 3 m fall), with a typical rope (34% stretch for a 9.1 mm Beal Joker), results in a total gravitational energy of 2,207 J and an impact force of 4.33 kN assuming that only the rope to the first piece of gear stretches.

Table 1. Parameters to determine impact force.

Gravitational energy (J)	2,207
mass, m (kg)	75
g (m/s^2)	9.81
height, h (m)	3

Rope out (m)	1.5
Absorption from rope stretch x (m)	0.51
Impact force, F (N)	4,328

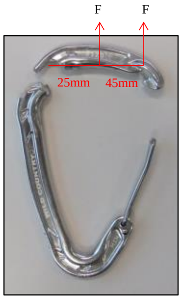
Next, we identify the stress in the section as

$$\sigma = \frac{My}{I}$$

Where M is the moment (F.z), z being the moment arm (i.e. distance from crack to loading point on the karabiner), y is the distance to the neutral axis and I is the moment of inertia. Two cases were considered, x = 45 mm, where the nose is assumed to be jammed and create a moment on the karabiner, or x = 25 mm, an arbitrary distance along the karabiner.

Table 2. Parameters to determine stress at the damage in the karabiner.

F (N)	x (mm)	M (Nmm)	I (mm^4)	y (mm)	σ (MPa)
4328	45	194757	981	5.278	1048
4328	25	108199	981	5.278	582



Schematic

Where F is the dynamic Force; x, the displacement of the force creating a bending moment; I is the moment of inertia; y distance to the neutral axis (assumed constant for the section, regardless of crack) and σ, the resulting stress.

Using

$$K_c = Y\sigma\sqrt{a}$$

and

Table 3. Parameters for the determination of stress as a function of crack length.

Fracture toughness, K_c MPa√m	Range 20-29, 25 used*
Y	1.99 (for small cracks)
Stress, σ (MPa)	f(a)
Crack length, a (mm)	Variable

*http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA7075T6

We may determine the stress, σ, as a function of crack length, a, shown in Figure 6. The graph shows the stress as a function of crack length with two points identified, 1,048 MPa for x = 45 mm, a = 0.14 mm, and 582 MPa for x = 25 mm, a = 0.47 mm. Although an estimate, the calculations suggest that the circa 0.55 mm starter crack, and the identified loading condition would be sufficiently large, to result in fracture of the WC Nitro karabiner. Such a depth of crack, based on the grooves that have been observed, seems reasonable.

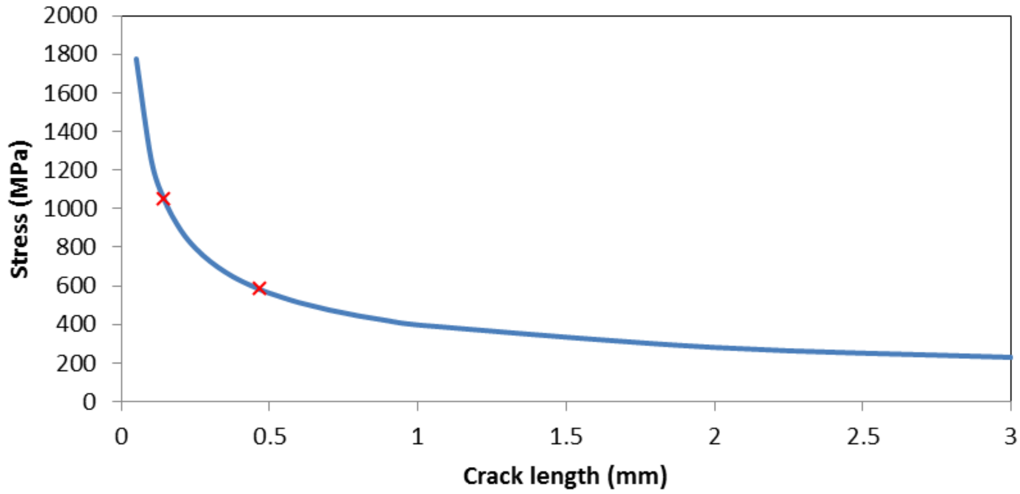


Figure 6. Graph to show the crack length dependence of stress. Two cases: x = 45 mm and x = 25 mm identified as red crosses.

CONCLUSIONS AND RECOMMENDATIONS

The received karabiner, a Wild Country Nitro is a relatively new model, and appeared to be in good condition generally. It is apparent that there is quite some damage, probably from contact with various bolts during use. These abrasions have resulted in many “starter cracks” in the Aluminium alloy karabiner. Analysis shows that stresses may be sufficiently large, for failure to occur by an excessive bending moment that resulted fracture initiation from the abraded region in the karabiner, where the bending stress would have been of largest magnitude. Therefore, it is concluded that the karabiner probably failed due to wear and tear, followed by an unfortunate loading situation, rather than via a manufacturing or design fault.

This case re-iterates the need for careful examination (and retirement when necessary) by the user, when using lightweight equipment. Whilst this karabiner fulfils test standards for a karabiner, the user must be aware of the intended use by design, where in this case, I believe the product is an all-purpose product, not specifically designed to meet the rigours of repeated falls/heavy wear that occur during working or red-point attempts that may occur when sport climbing.